USASRDL Technical Report 2225

WIND-MEASURING SET AN/TMQ-13(XE-2)

by

Donald E. Johnson

and

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September 1961

U.S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY

FORT MONMOUTH, N. J.

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DA Task 3D36-21-004-01

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ABSTRACT

The general development of Wind-Measuring Set AN/TMQ-13(XE-2) is discussed, and a detailed review is made of the design-modifications that have been incorporated in the service-test model. A brief summary is made of the theory of design and of the system errors.

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Figures (contd)

INTRODUCTION

In this report the development, design, and modification of an experimental equipment for the measurement of low-level winds are reviewed. Details of design and modifications intended to make the (XE-2) model (Figs. 1 and 2) of the Wind-Measuring Set AN/TMQ-13 an improved tactical system are discussed.

BACKGROUND

In early 1954 USASRDL personnel suggested that a pilot-balloon technique be evolved to measure low-level winds for the Honest John missile program. For security reasons, the suggestion was judged impractical, and the idea lay dormant for about two years. In 1956 USASRDL initiated a program designed to determine the feasibility of using a balloon to measure rocket winds. Experiments proved the balloon technique to be feasible and sufficiently promising to warrant further investigation.

On 13 Jun 1956 the Heavy-Rocket Steering Committee recommended that a double-theodolite wind-measuring set be produced and submitted to USAAB for engineering evaluation. The Meteorological Division, USASRDL, then devised a system that uses two theodolites to track a pilot balloon.

In April 1958 an engineering model was submitted to USAAB for evaluation. This model consisted of the following equipment: two Theodolites ML-247, one set of Nomograms ML-53E( )/4, one variable interval timer, two Head and Chest Sets HS-25( ), one 10-gram nozzle, one transmission line, several 30-gram pilot balloons, and two instruction books. These components did not make up a complete wind-measuring set, but they were deemed adequate for an engineering evaluation of the balloon technique in view of the priority of the project and the urgent need for an improved wind-measuring system.

On 9 June 1959 an evaluation report dated 19 Feb 59 was received from OCSigO.[1] This report stated that USASRDL should continue development work on the wind-measuring set, correct the deficiencies listed, and provide two sets for service-test by USCONARC.

In June 1959 a plan designed to accomplish the assigned task was formulated, and work was started on various phases.

DISCUSSION

Technical Characteristics of Major Components

1. Aiming Circle M2 (Fig. 3)

   Limits of traverse: azimuth - unlimited
   elevation - 800 mils
   depression - 400 mils
   telescope power - 4X
   field of view - 10°

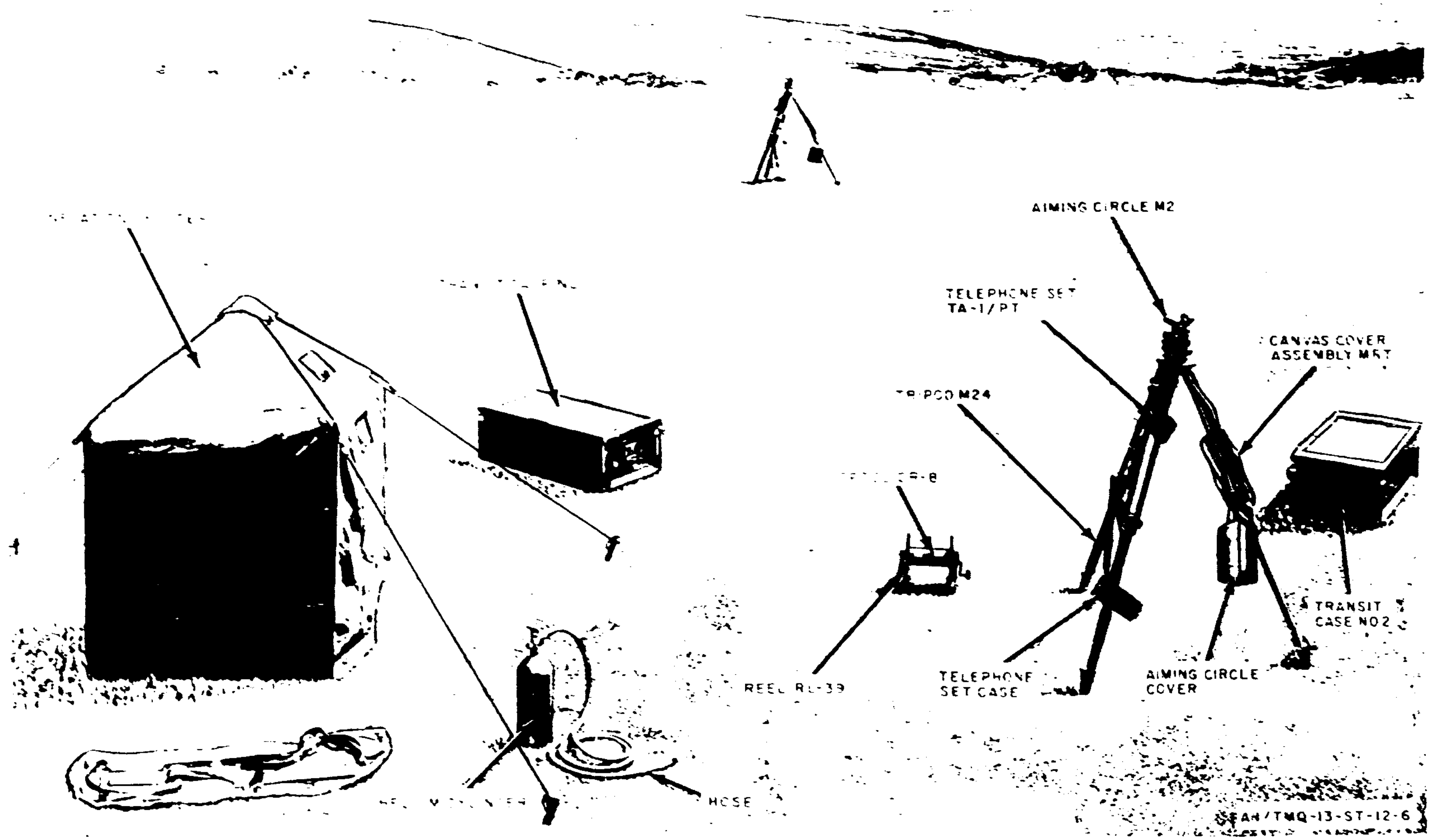


Fig. 1. Wind-Measuring Set AN/TMQ-13(XE-2), Installed

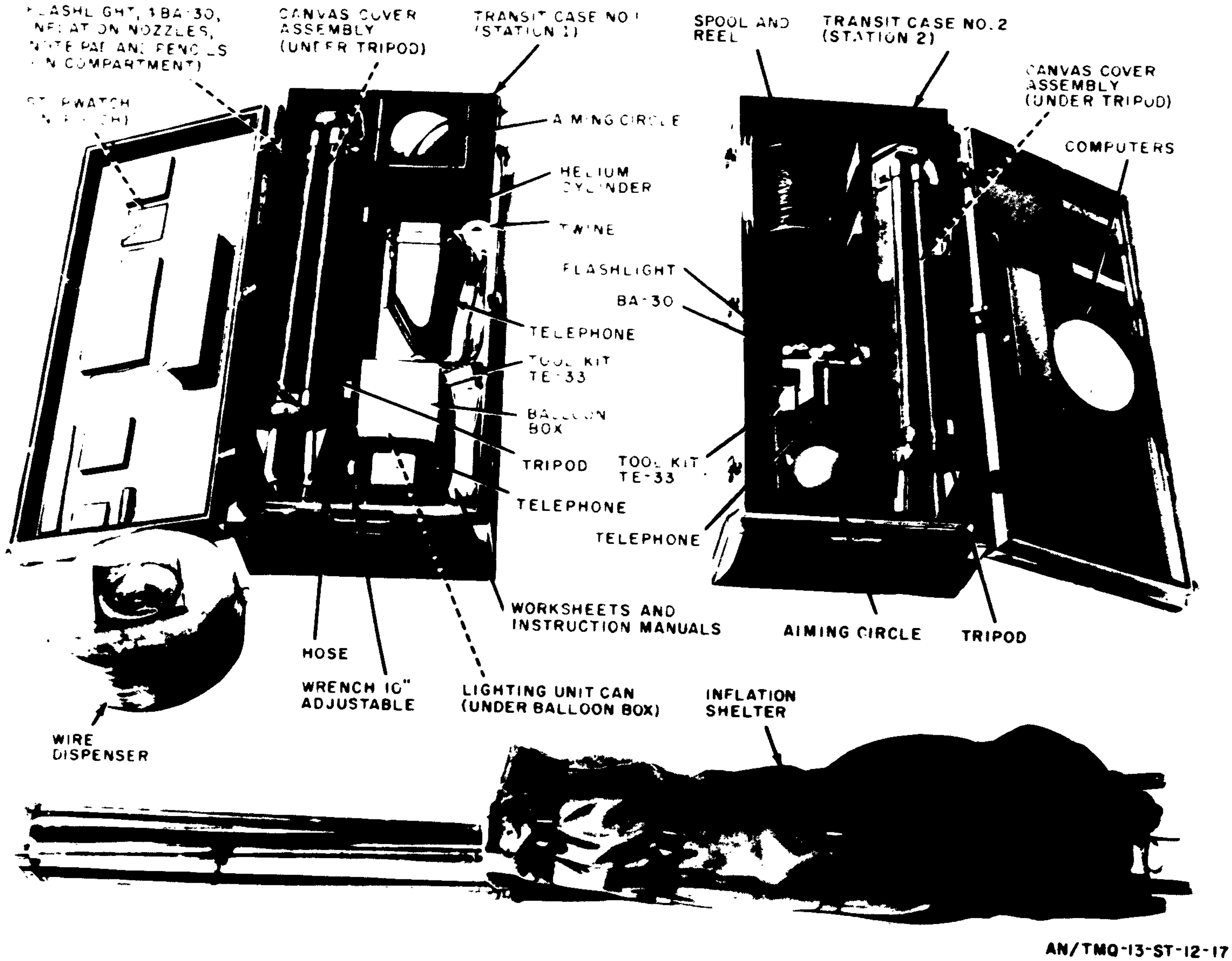


Fig. 2. **Wind-Measuring Set AN/TMQ-13(XE-2) in Transit Cases**

Fig. 3. Aiming Circle Mounted on Tripod

Scale graduation: azimuth - coarse scale: 100 mils
numbered each 200 mils
micrometer scale: 1 mil
numbered each 10 mils

elevation - coarse scale: 100 mils
numbered each 100 mils
micrometer scale: 1 mil
numbered each 10 mils

Reticule crossline graduations: 0 to 85 mils in increments of 5 mils
numbered each 10 mils

Weight: 21 lbs

Height, extended with equipment: $5\frac{1}{2}$ ft

2. Balloon ML-64A (Fig. 4)

Type: pilot
Color: red
Rate of rise (20 grams free lift): approximately 400 ft/min
Weight: 30 grams

3. Lighting Unit (Fig. 5)

Type: Weather Bureau type 5
Weight: 20 grams, activated
Method of activation: water immersion
Life expectancy: 30 minutes maximum
Activation time: 30 seconds
Battery voltage: 3.5 volts
Battery type: Ray-O-Vac type RSC3
Bulb rating: 3.8 volts

4. Helium Cylinder (Figs. 4 and 6)

Pressure: 1800 lbs per sq in
Maximum test pressure: 3000 lbs per sq in
Capacity: 218 cu in
Weight: 10 lbs
Dimensions: 17-3/4 x 5.2 in

5. Timer (Fig. 7)

Dial graduation: 60 to 0 seconds, increments of 1 second;
numbered every 5 seconds

6. Telephone Set TA-1/PT (Fig. 8)

Frequency range: 300 to 4000 cps
Signaling voltage: 65 to 80 volts at 20 cps
Operating range: 5 miles
Weight: 3-1/4 lbs
Dimensions: 10 x 4-1/4 x 3-1/2 in

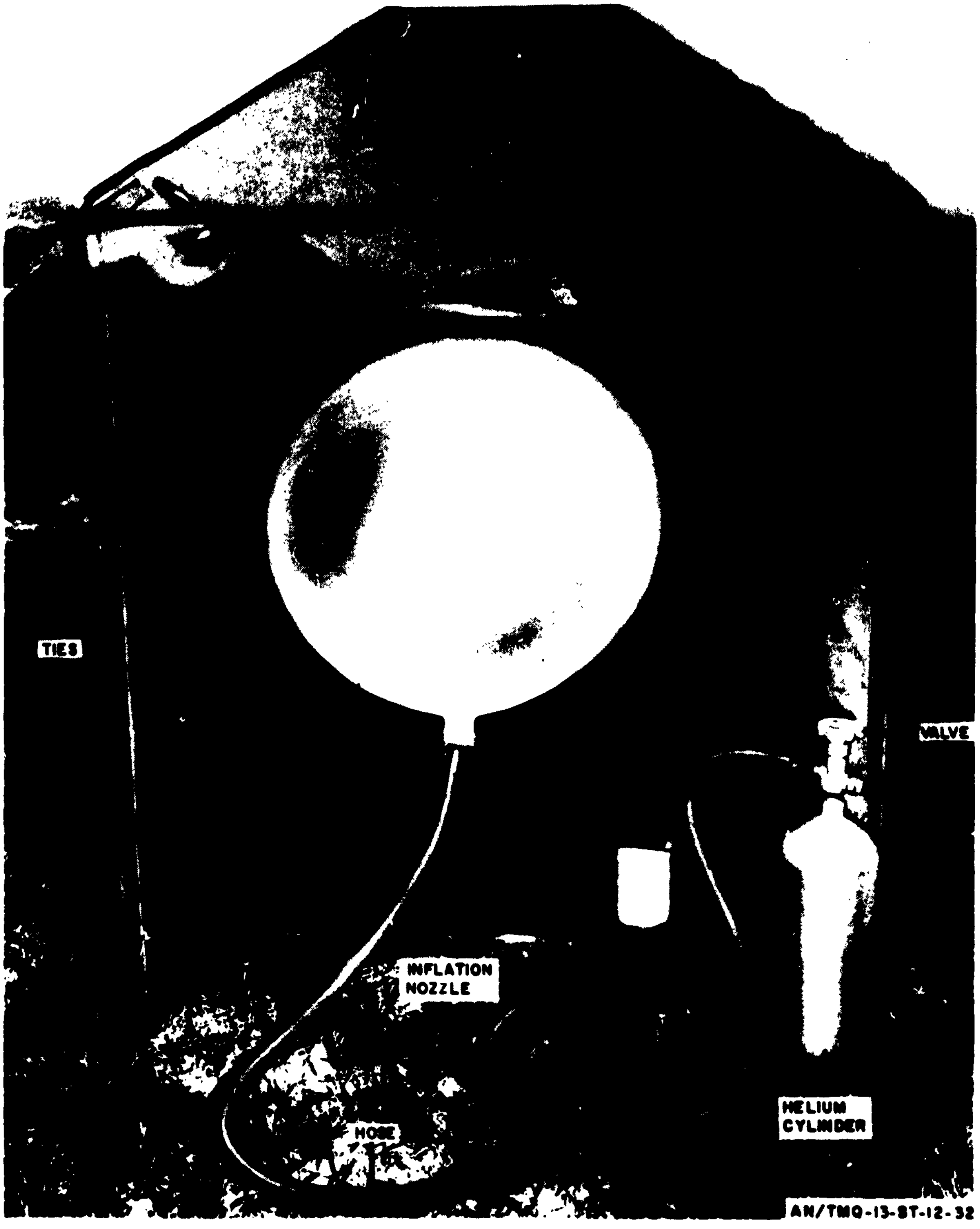


Fig. 4. Balloon ML-64A Shown in Inflating Setup

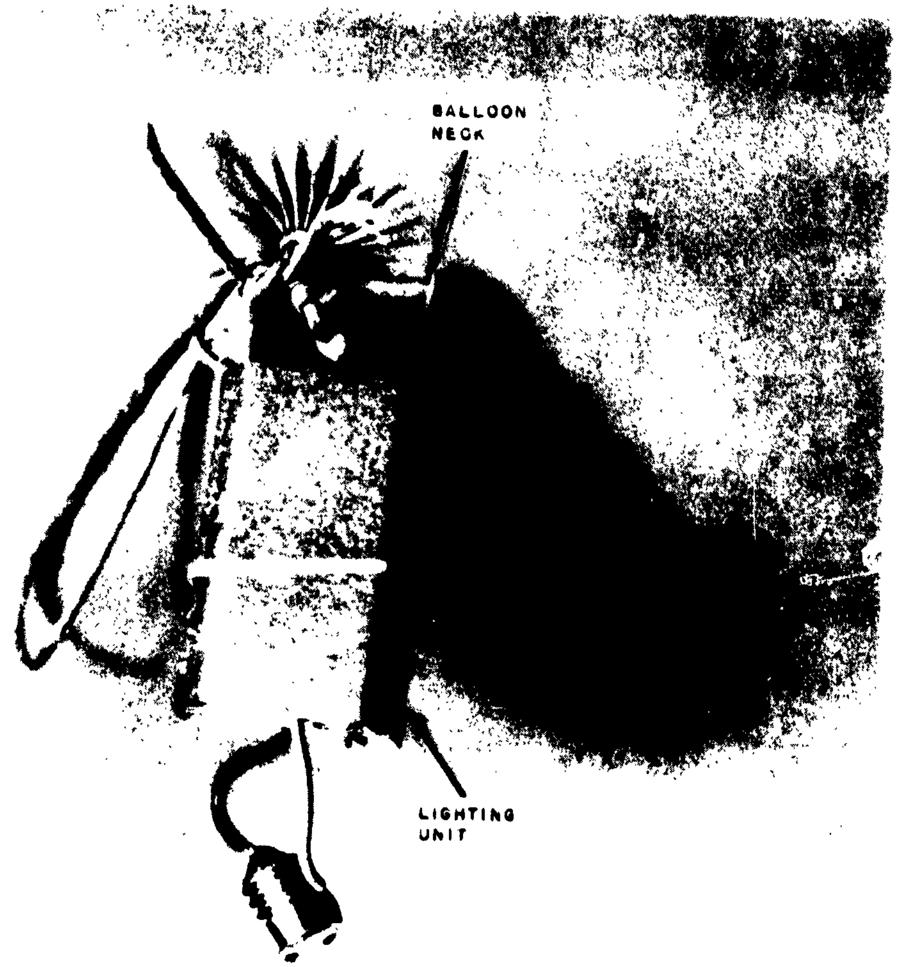


Fig. 5. Lighting Unit Tied to Balloon

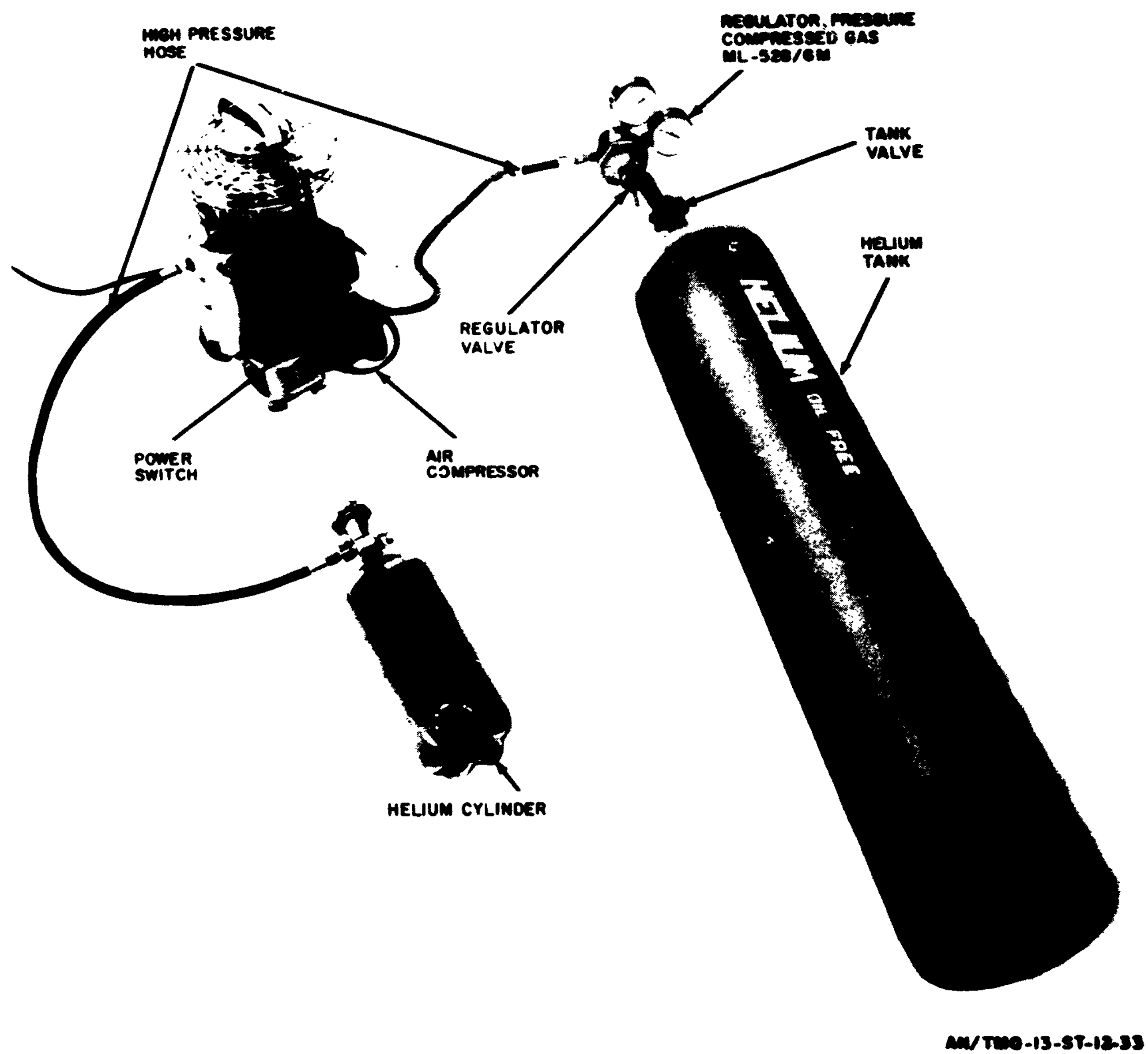


Fig. 6. Helium Cylinder Filling Arrangement

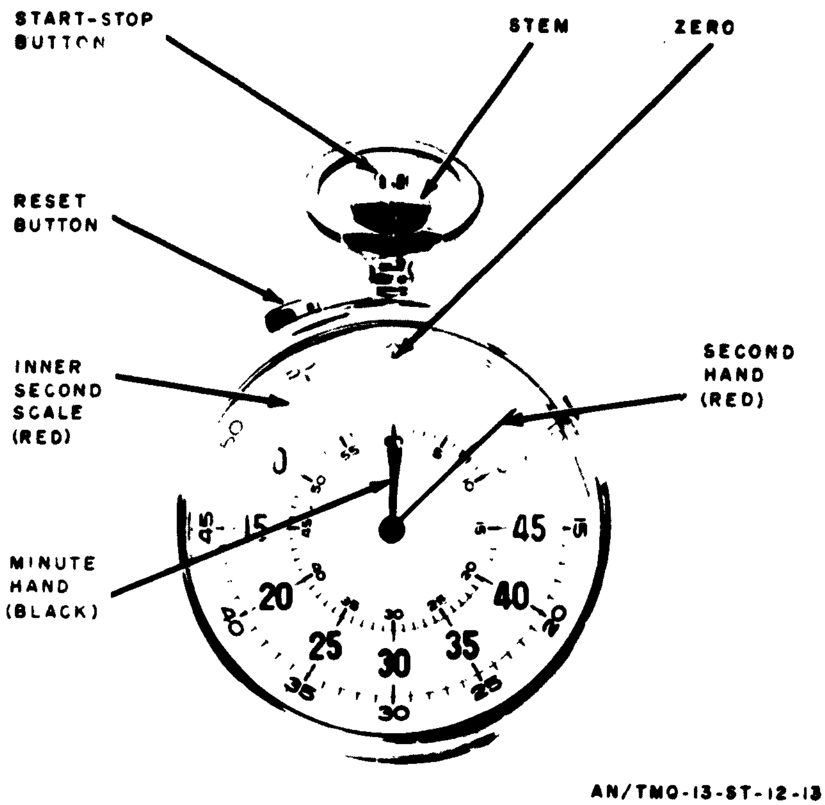

START-STOP BUTTON
STEM
ZERO
RESET BUTTON
INNER SECOND SCALE (RED)
SECOND HAND (RED)
MINUTE HAND (BLACK)
AN/TMQ-13-ST-12-13

Fig. 7. Timer

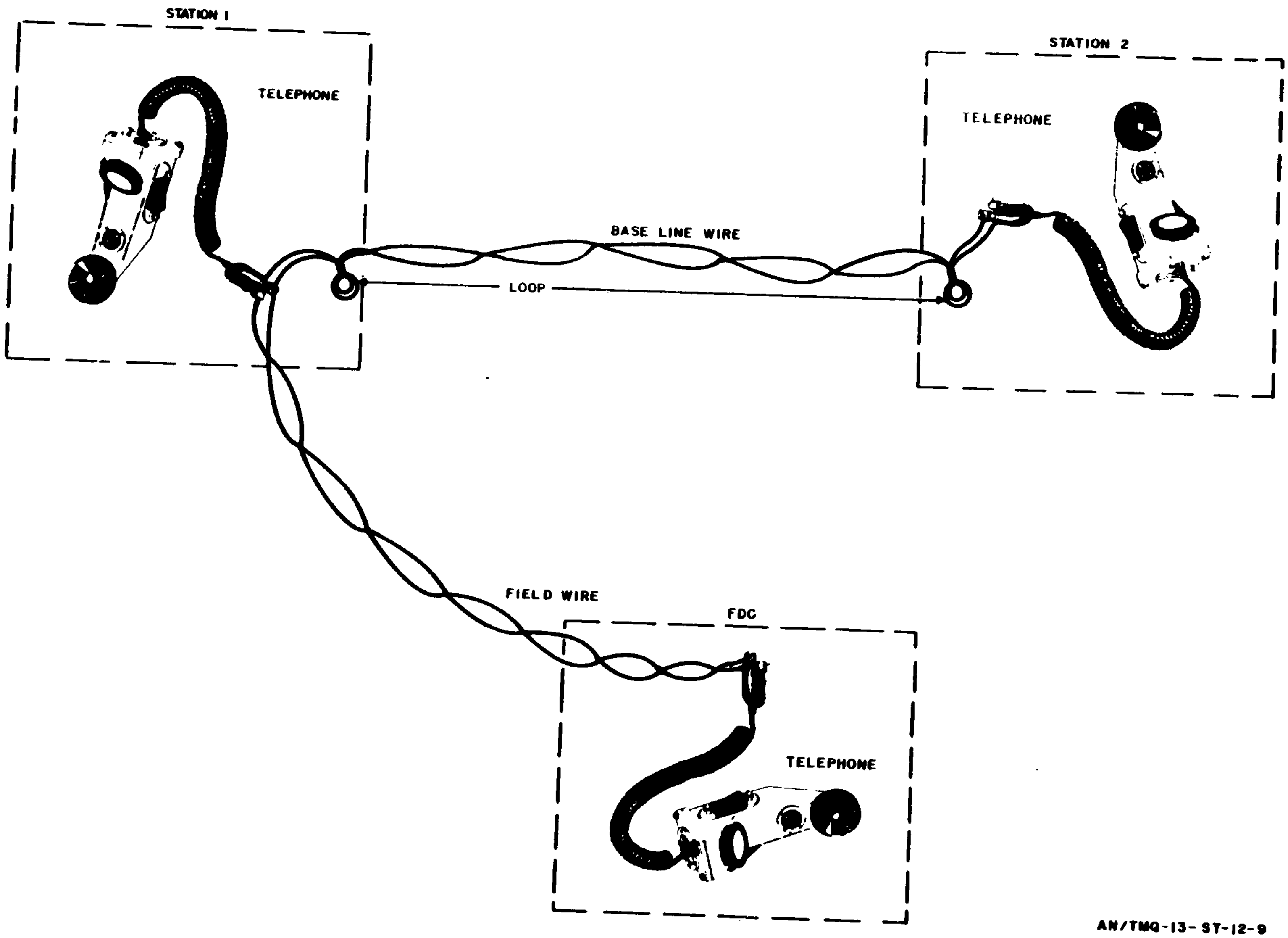


Fig. 8. Communication and Signaling System Diagram

7. Wind Computer (Figs. 9 through 15)

Diameter: 11-1/4 in
Weight: 2 lbs

8. Inflation Shelter (Figs. 4 and 16 through 19)

Dimensions: ejected, 58 x 39 x 39 in;
collapsed, 71 x 9 x 8 in
Weight: 33 lbs

9. Transit Cases (Shown in Fig. 2)

Dimensions: 13 x 19 x 38-3/4 in
Weight: case I, 55 lbs; case II, 46½ lbs

Miscellaneous Components (Fig. 20)

Telephone Sets TA-1/PT
Reel, RL-39
Spool, DR-6A, with transmission cable, 400 ft
Helium cylinder
Hose assembly
Balloon inflation nozzle, 20 grams
Flashlights, MX-991/4
Field wire WD-1/TT in dispenser (½ mi length)
Waxed twine
Pilot Balloon ML-64A
Pilot-balloon container
Balloon-lighting unit
Balloon-lighting-unit container
Shield for lighting-unit bulb

Tools furnished with the wind-measuring set are shown in Fig. 21.

Theory of Design

The theory underlying the design of the AN/TMQ-13 is comprehensively covered in reference 2. It is beyond the scope of this report to discuss the theoretical analysis of the s stem.

Generally, this system depends on the measurement of angles, which are obtained while tracking a balloon, from the end positions of a fixed baseline. These angles are measured in exact synchronization at the end of a time-interval. This time-interval is determined by the intended quadrant elevation of the missile and the wind-profile condition existing at the time of fire.

The data which this system delivers are a weighted rocket wind velocity, which resolves into orthogonal vectors of a range wind, and a cross wind. The resultant data are the meteorological winds weighted by the effect of the wind on the rocket as a function of distance along a trajectory.

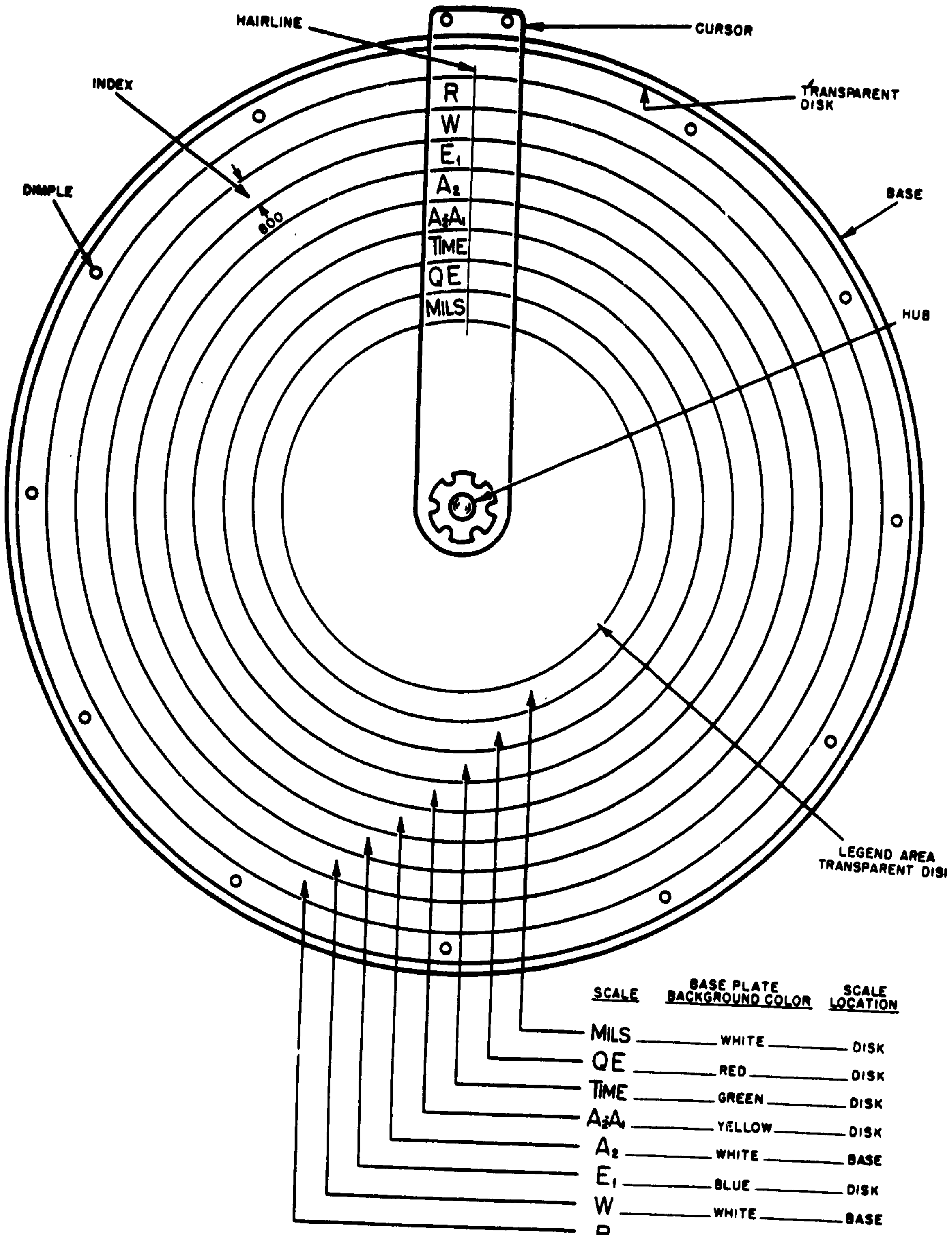


Fig. 9. Computer Scale Configuration

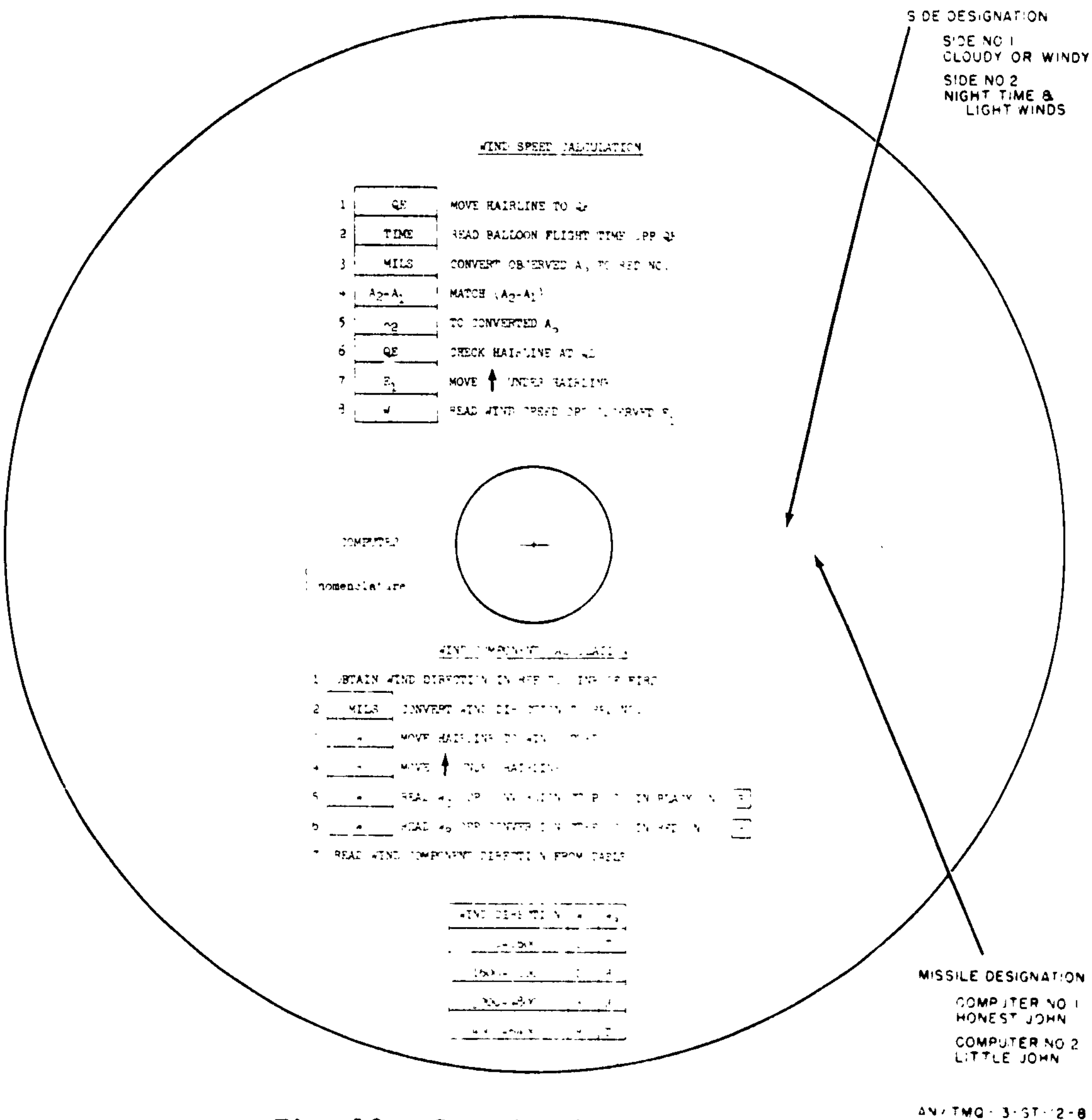


Fig. 10. Computer Legend Area

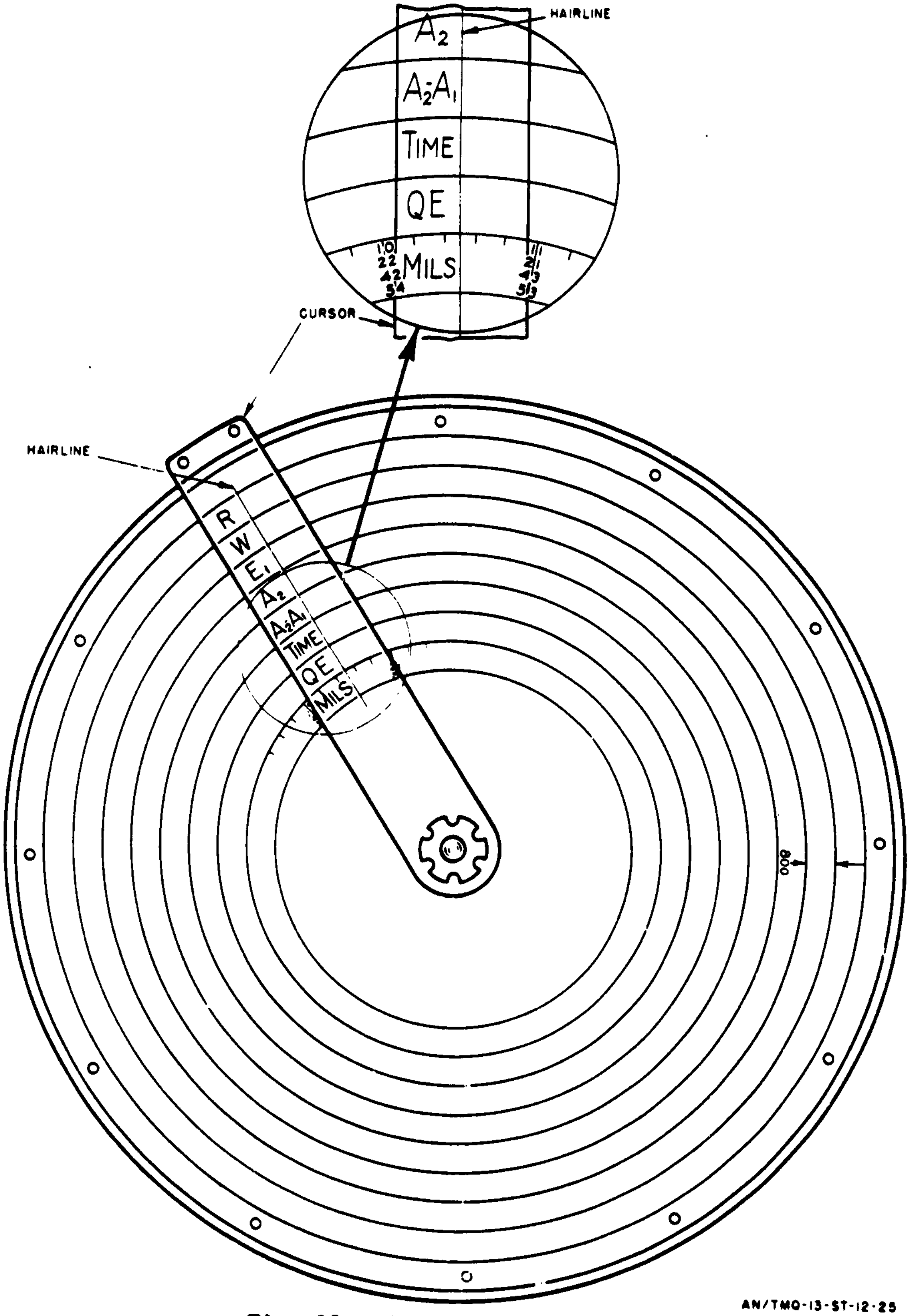


Fig. 11. Computer Mils Scale

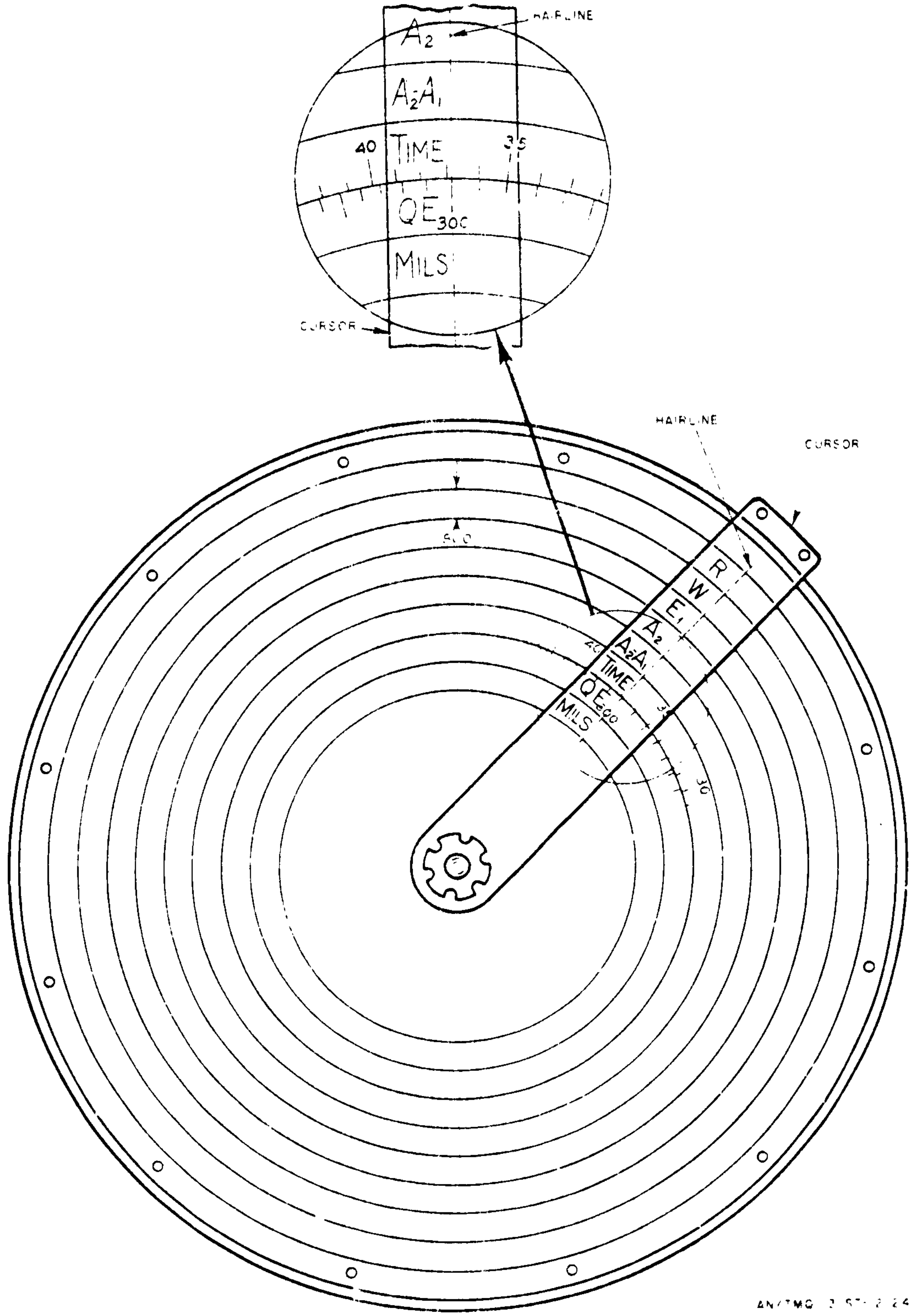


Fig. 12. Computer QE and Time Scales

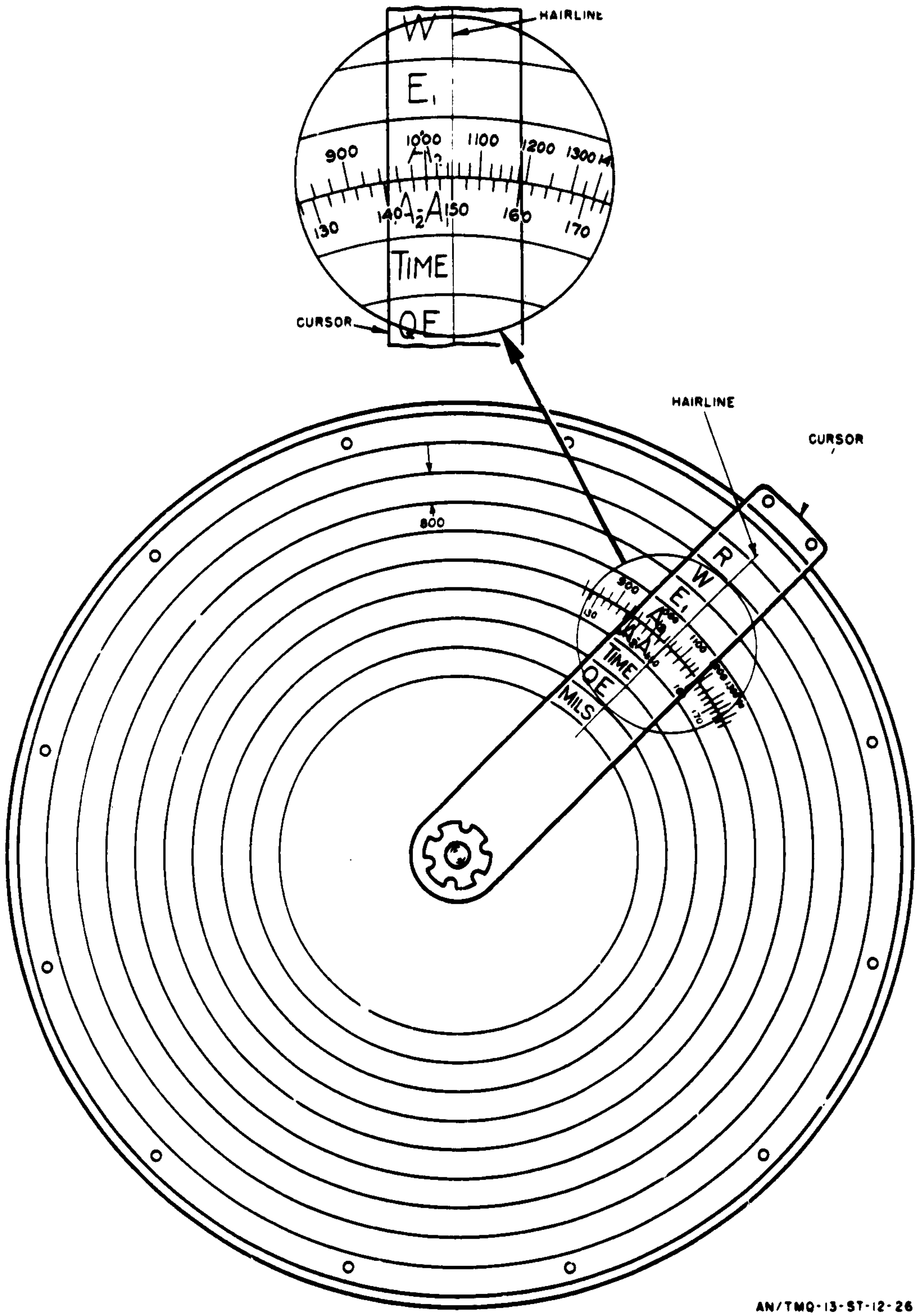


Fig. 13. Computer $A_2 - A_1$ and A_2 Scales

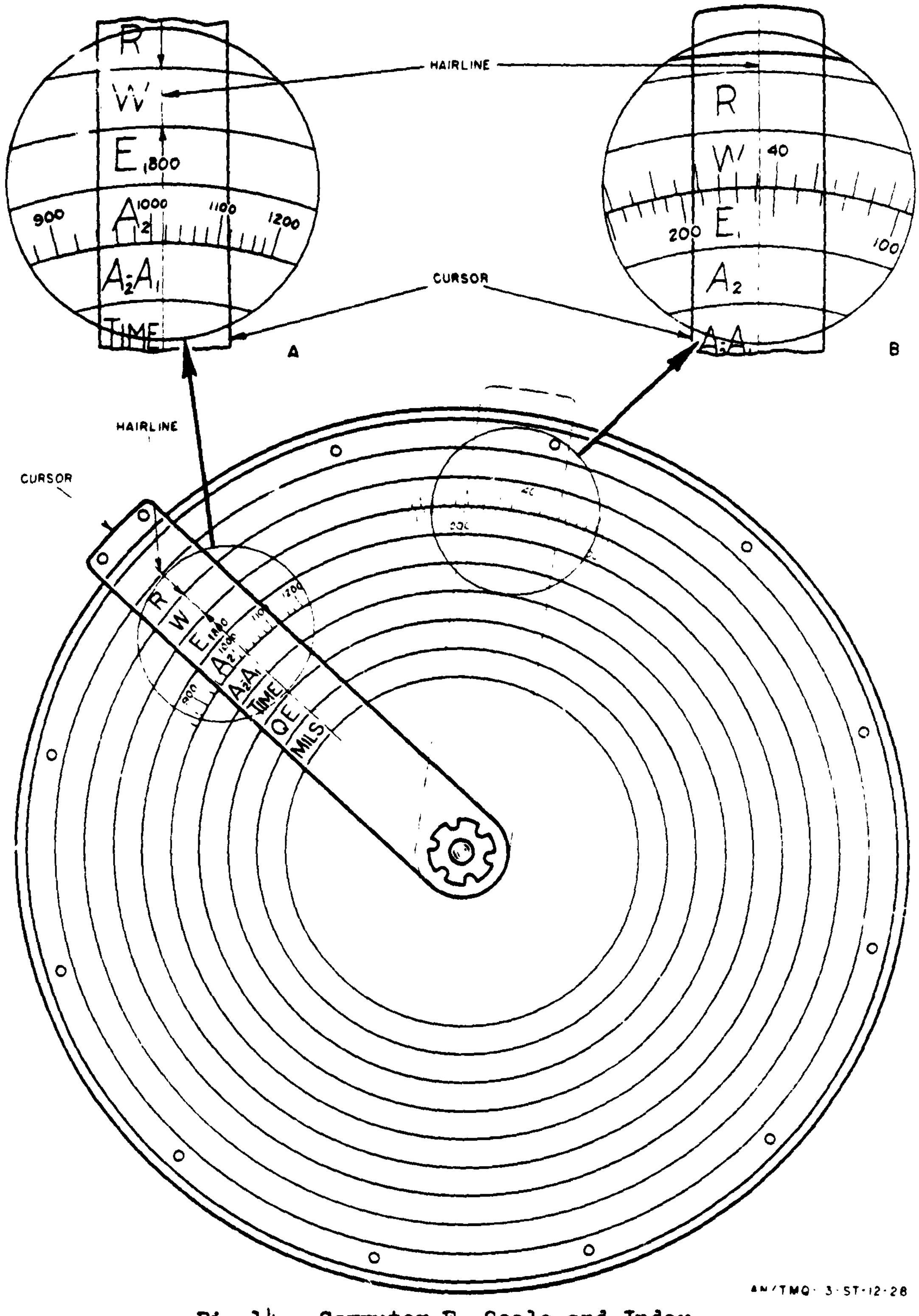


Fig 14. Computer E_1 Scale and Index

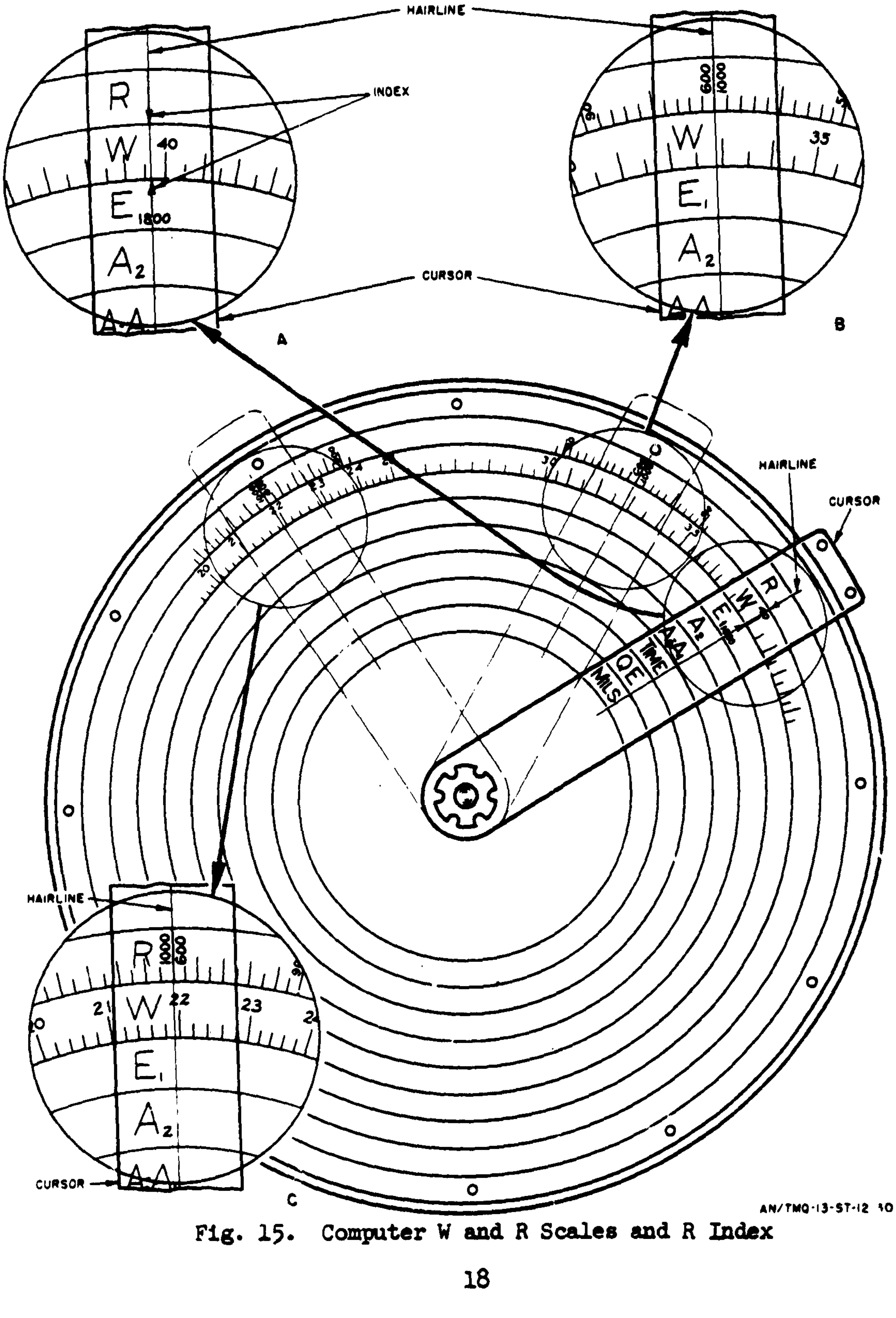


Fig. 15. Computer W and R Scales and R Index

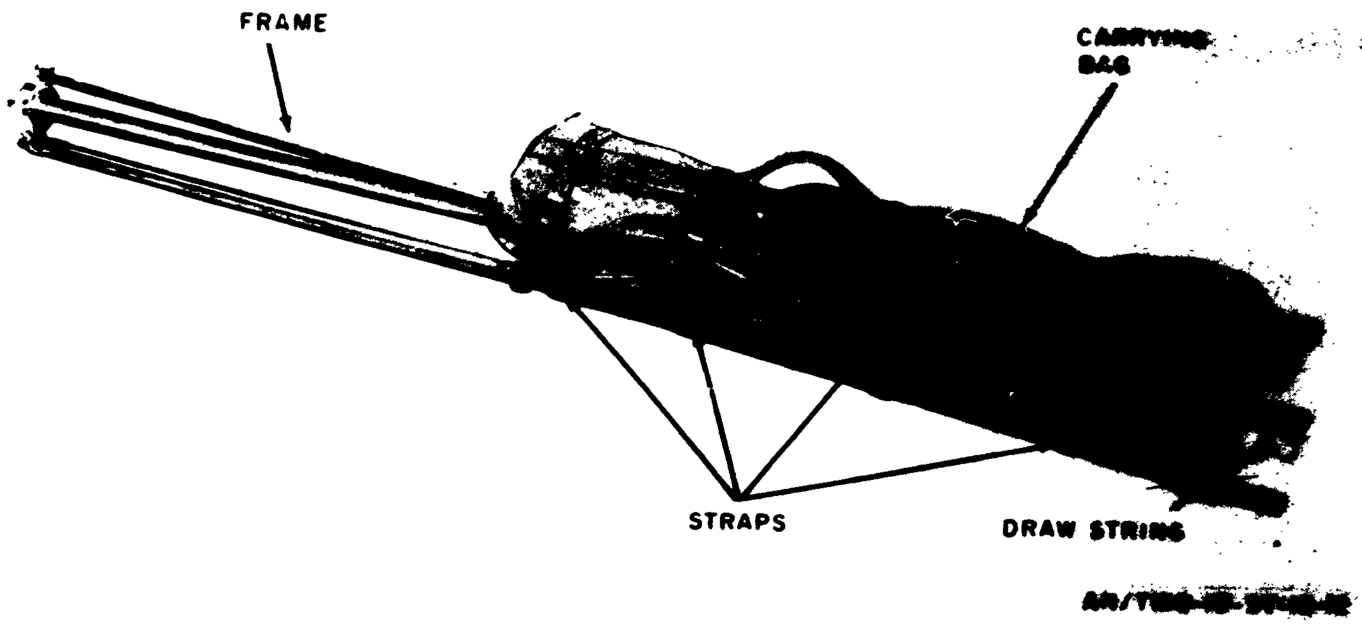


Fig. 16. Balloon Inflation Shelter in Transit Position

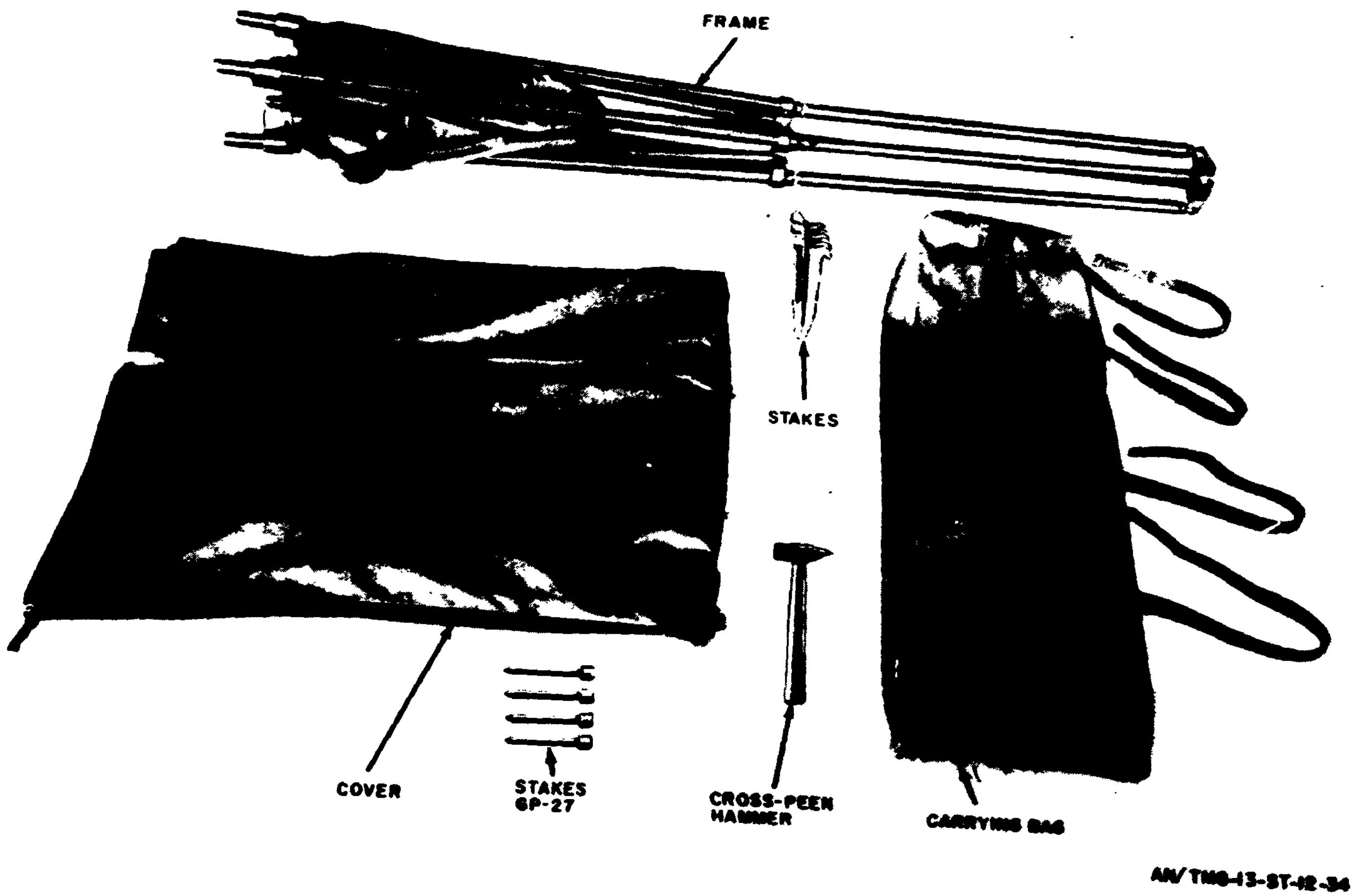


Fig. 17. Balloon Inflation Shelter, Unpacked

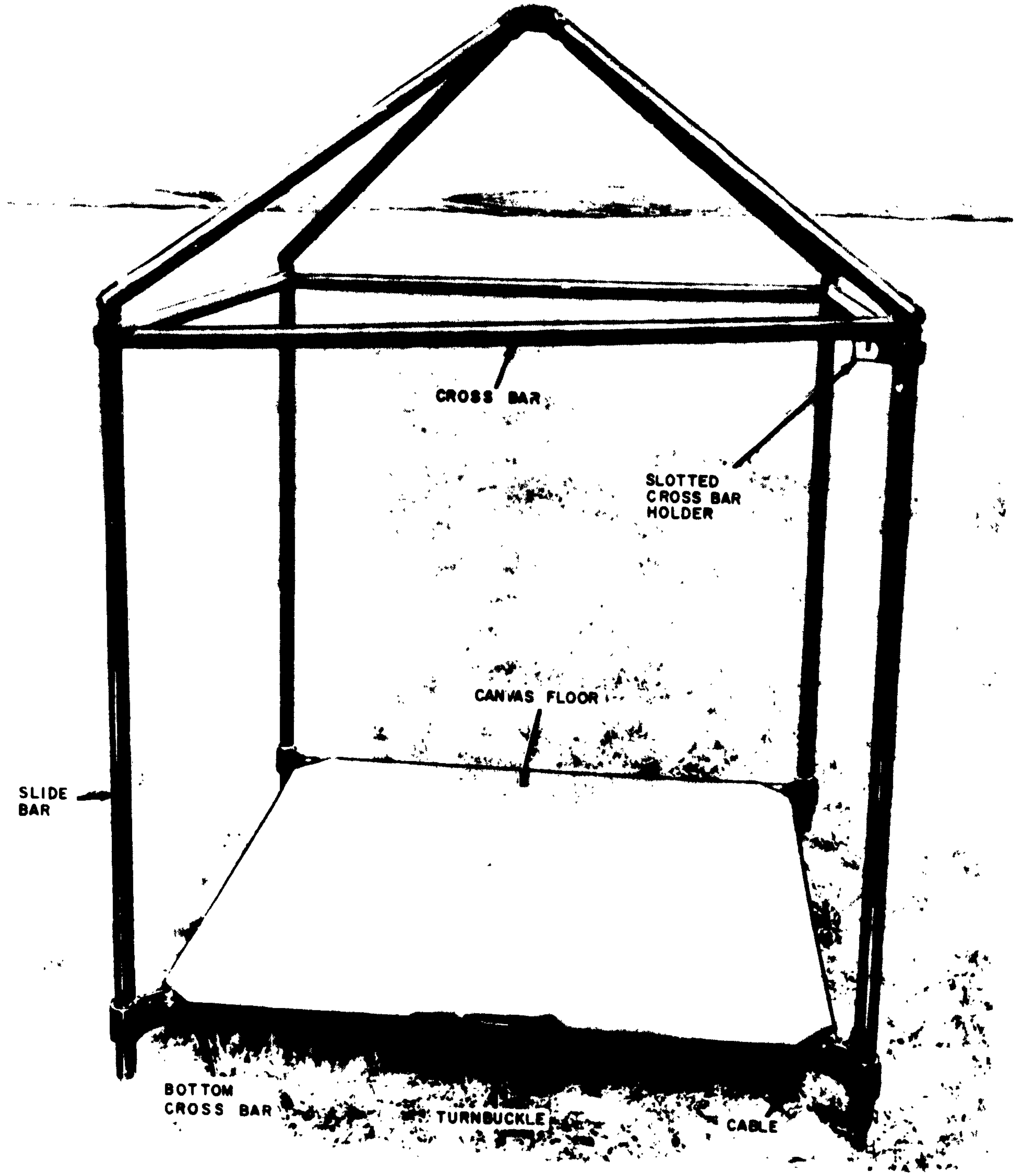


Fig. 18. Balloon-Inflation Shelter Frame, Erected

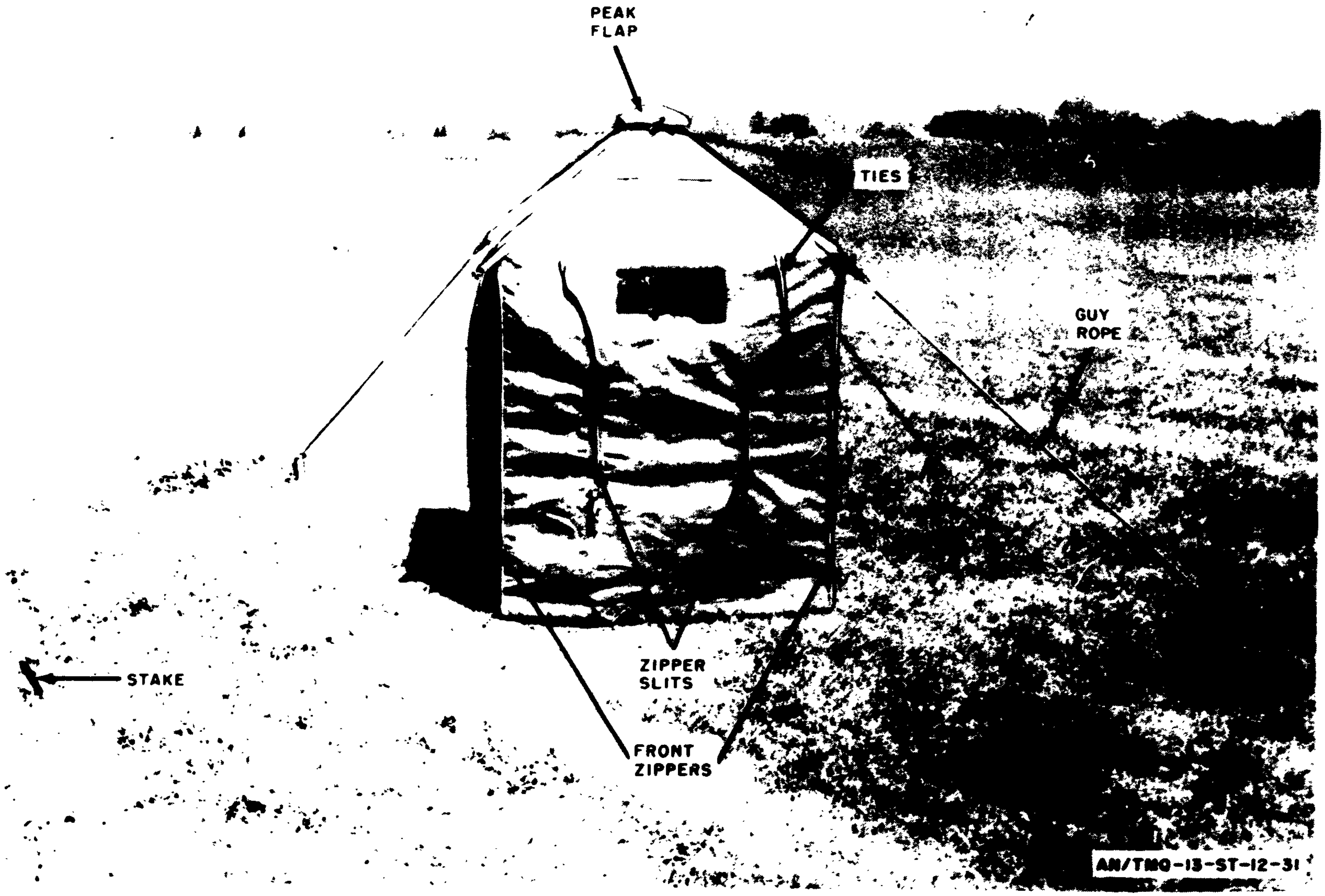
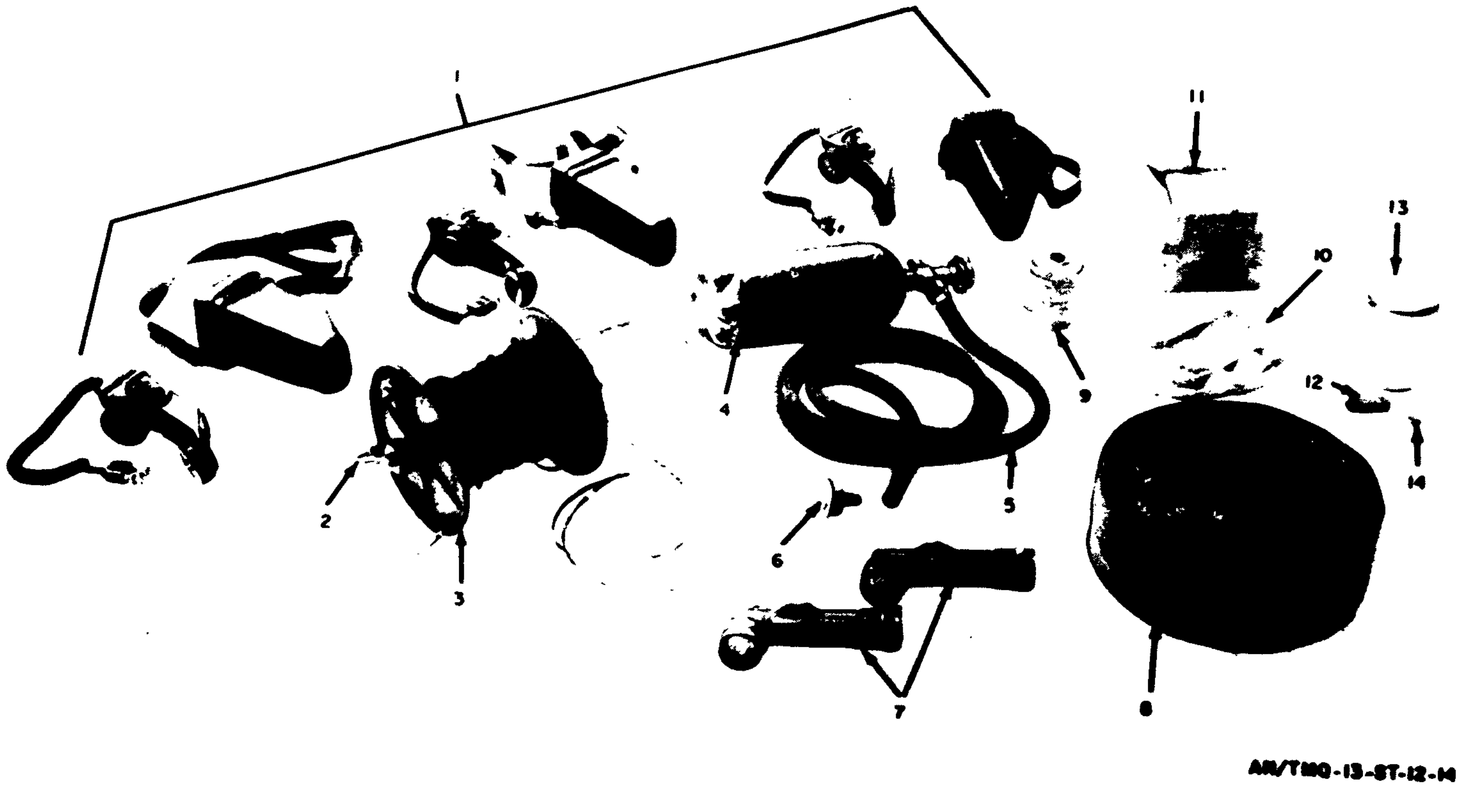


Fig. 19. Balloon-Inflation Shelter, Erected



Legend:

1. Telephone Set TA-1/PT	2. Reel RL-39	3. Spool DR-8
4. Helium cylinder	5. Hose	6. Inflation nozzle
7. Flashlight MX-991/U	8. Dispenser, Wire MX-306/AG w/½ mile Wire WB-1/TT	
9. Twine	10. Balloon ML-64A	11. Balloon box
12. Lighting unit	13. Lighting unit can	14. Light shield

Fig. 20. MISCELLANEOUS COMPONENTS

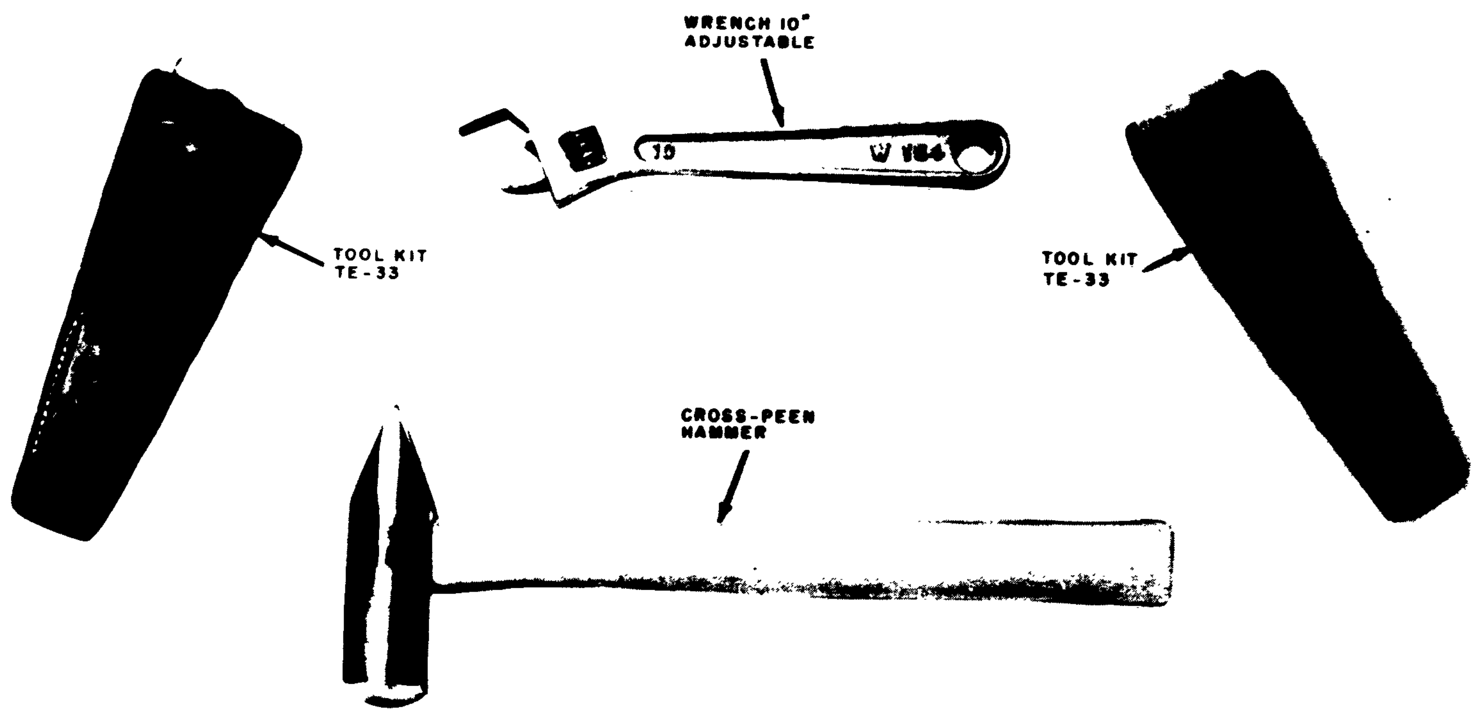

WRENCH 10"
ADJUSTABLE
TOOL KIT
TE-33
TOOL KIT
TE-33
CROSS-PEEN
HAMMER

Fig. 21. TOOLS

The equation for the weighted rocket wind can be reduced to the following form (see reference 2):

$$W_r = F \sin^{(1-n)} a_2 \csc^{(1-n)} (a_2 - a_1) \operatorname{ctn}^{n} e,$$

where

a_1 = azimuth angle to balloon from station No. 1,

e_1 = elevation angle to balloon from station No. 1,

a_2 = azimuth angle to balloon from station No. 2,

n = wind-profile index,

F = a number depending on the length of the baseline, the balloon flight time, and the quadrant elevation at which the missile is to be fired.

The system is designed to obtain the required weighted rocket wind from one complete balloon observation. This is done by knowing the quadrant elevation at which the missile will be fired and--from this information--obtaining a balloon flight-time from the computer, flying the balloon for the required period, observing the balloon's angular position, entering the angular data on the computer, and calculating the range and cross-wind speed.

Deficiencies and Modifications

The deficiencies pointed out in "Summary of Tests," para. 5 of reference 1, were noted, and the equipment was redesigned and modified accordingly. Procedural changes were also made in the operating instructions where specific deficiencies were indicated.

These changes and modifications were made as follows: (Numbering agrees with that of reference 1.)

a. Equipment

1. White balloons were difficult to observe against overcast skies.

Modification 1. Red balloons (ML-64A) are being supplied with the set.

2. The required "weighing off" of balloons for 10-gram free lift was difficult.

Modification 2. The 10-gram free-lift requirement has been deleted. A 20-gram free lift is now specified, and a 20-gram inflation nozzle has been designed for this specific purpose. (Figs. 4 and 20)

3. A shelter was required for balloon inflation.

Modification 3. A portable balloon-inflation shelter has been designed and has been provided as part of the set. (Figs. 4, 16 through 19)

4. Balloon night lights required a cover before balloon release.

Modification 4. Balloon night-light covers have been provided. The balloon night lights can be blacked out by use of the cover and/or by storing them in the inflation shelter efore release.

5. Helium was in limited availability.

Modification 5. A Hydrogen Generator ML-303/TM with accessories has been provided as suggested. However, this generator is not listed as being part of the wind set. It has been recommended that a small helium-filled cylinder be used for inflating the pilot balloons. (See the appendix to this report and Figs. 4 and 6.)

6. Because of weight and bulk, the head and chest sets interfered with tracking operations.

Modification 6. Telephone Set TA-1/PT has been substituted for Head and Chest Set HS-251. (Fig. 8)

7. Plugs provided for the transmission line were excessively complicated and subject to accidental grounding.

Modification 7. These plugs have been deleted.

8. Use of "Cannon" plugs on the timer power-supply cables was excessively time-consuming.

Modification 8. The Cannon plugs have been deleted.

9. A cover was required for the nomogram, but was not provided.

Modification 9. The nomograms have been deleted.

10. Measurement of the baseline by one man was difficult.

Modification 10. The transmission cable has been modified to facilitate measurement of the baseline. (Fig. 22)

11. Setting up the theodolites required an excessive amount of time.

12. Blackout lights on the theodolites were excessively bright.

13. Theodolites did not read in mils, but in degrees.

14. Covers for the leveling bubbles on the theodolites were required, but were not provided.

15. Theodolites and tripods were difficult to carry across rough terrain.

Modifications 11, 12, 13, 14, and 15. The Aiming Circle M2 (reference 3) with Tripod M24 has been substituted for Theodolite ML-247 and Tripod ML-78. (Figs. 1 and 3)

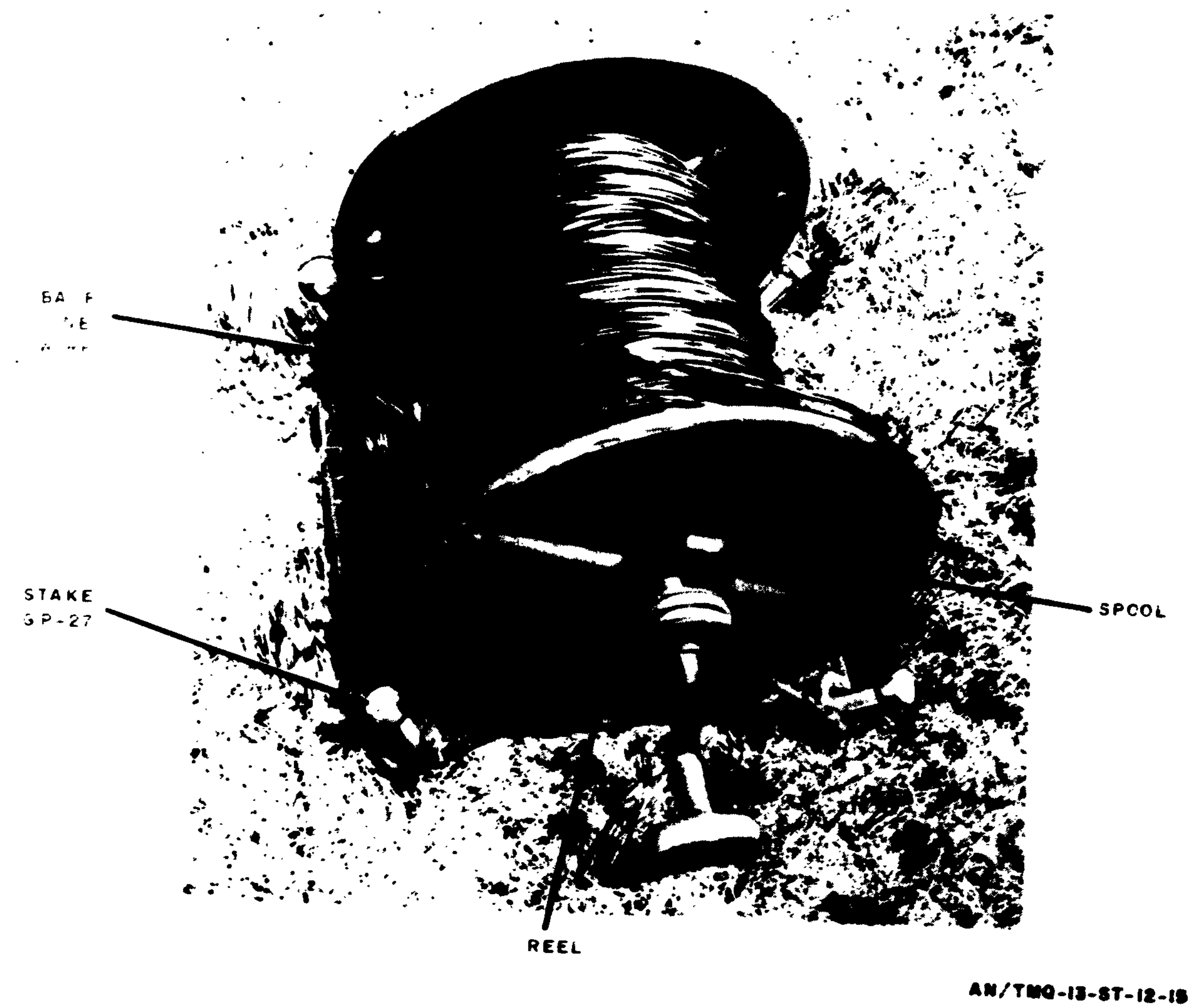


Fig. 22 Baseline and Transmission Cable on Reel

16. A means of communication was required to connect the theodolite operators with the fire-direction center.

Modification 16. Hand Set TA-1/PT is provided as the fire-direction center's communications instrument, and Field Wire WD-1/TT (one-half mile) in Wire Dispenser MX-306A/G (Fig. 2) is provided as a means of connecting the theodolite operators to the fire-direction center.

17. Nomograms did not read in mils.

18. Probability of personnel error in the use of the nomograms was high.

19. Reading of nomogram scales was difficult.

Modifications 17, 18, and 19. A circular slide rule which is graduated in mils has been substituted for the nomograms (Figs. 9 through 15). Two slide rules have been provided. The Computer, Wind CP-553(XE-1)/UM is for use with the Honest John; and Computer, Wind CP-554(XE-1)/UM is for use with Littlejohn.

20. The variable interval timer was unnecessarily sophisticated.

Modification 20. A stop watch has been substituted (Fig. 7).

b. Operating Instructions

1. Balloon conditioning (soaking in boiling water for five minutes) was unnecessary for low-level work.

Modification 1b. The requirement for soaking the balloons has been deleted from the instructions.

2. Computation of the final corrections was a difficult task for either theodolite operator because of the requirement for light and for a protected working space.

Modification 2b. It is specified that wind computations be accomplished in the fire-direction center. A worksheet has been provided to aid computation (Fig. 23).

3. Orientation of the baseline perpendicular to the wind direction, as required for least error, was difficult.

Modification 3b. The instructions state that a trial balloon should be released to determine the approximate direction of the wind for orientation of the baseline.

Design Details

The 20-gram inflation nozzle (Modification 2, Fig. 4), was designed and made internally. It is a sleeve and 2-inch disk with a 2-inch-long nozzle approximately 5/8 inch in diameter. It is made from a phenolic material and has a rubber flapper valve that allows gas to enter the balloon, but does not allow it to escape.

WORKSHEET

Wind Measuring Set AN/TMQ-13

Heading

Date: 25 MAY 60   Time: 1010

Observer 1: J. JONES   Observer 2: P. SMITH

Nighttime wind estimation: Less than 8 mph ____ Greater than 8 mph ____

Balloon flight time:

1. QE 300   2. Balloon flight time 37

Orientation:

	Right	Left
3. Angle Alpha	1,300	
	+3200	-3200
4. Station one setting	4,500	
5. Angle Bravo	2,200	

Balloon data:

6. Azimuth two (A_2) 2150   8. Elevation one 158

7. Azimuth one (A_1) 2000

Computations:

9. $A_2 - A_1$ 150

10. A_2 converted 4050

11. Windspeed 39.6

Wind components:

12. A_1 2000   17. Direction converted 4000

13. Angle Bravo 2200

14. Direction 4200

Component	Direction	Speed
Cross Wind	15. R	18. 32.8
Range Wind	16. H	19. 21.9

Fig. 23   AN/TMQ-13-ST-12-35

The balloon-inflation shelter (Modification 3, Figs. 4, 16, 17, 18, and 19) was internally designed and fabricated. It is basically a canvas covering which fits over a collapsible aluminum frame. The entire assembly, including stakes and a hammer, weighs approximately 35 pounds. The sheltered volume available for the inflation of balloons is approximately 40 cubic feet.

The balloon night-light cover, Modification 4, was internally fabricated and is simply a piece of black plastic tubing sealed off at one end.

The small cylinder, Modification 5, used to carry helium for balloon-inflation purposes, is a commercial item. It is approximately 5 inches in diameter and 17 inches high. Its capacity is about 15 cubic feet of gas at a pressure of 1800 pounds per square inch. This small cylinder is to be filled in a rear area from a standard-size helium tank, using a pressure regulator, air compressor, and high-pressure hoses. (See Figs. 4 and 6.)

The Telephone Set TA-1/PT, Modifications 6 and 16, is a sound-powered telephone which can be used on field-wire lines. It is standard Signal Corps equipment, which is fully described in Army Technical Manual TM11-2153.

The transmission cable (Modification 10, Fig. 21) is field wire which has been wound on Spool DR-8A and Reel RL-39. This cable serves two purposes. It is used to connect the telephone sets used at the two tracking positions and to measure the 400 feet of baseline distance. The 400 feet of length is measured off between two loops of wire in the transmission cable. The reel and spool combination can be staked down so that one man can conveniently extend the baseline.

The substitution of Aiming Circle M2 with Tripod M24 for Theodolite ML-247 and Tripod ML-78, Modifications 11 through 15, gives the set instruments which may be read directly in mils and which may be easily handled. The aiming circle cost is considerably less than that of the original theodolite. However, the Aiming Circle M2 is limited to an angle of 800 mils in elevation tracking. With the rate of balloon rise used in the wind-measuring set, this limitation means that the pilot balloon cannot be tracked to measure winds less than 4.8 miles per hour. Wind velocities from calm to 4.8 miles per hour could be measured if the Aiming Circle M2 were modified to have an elevation-tracking capability of 1600 mils. Engineers of the U. S. Army Ordnance have been studying the feasibility of incorporating improved elevation tracking into the existing Aiming Circle M2. They are not incorporating any of the tracking schemes they have evolved into pilot equipment, but they are extending their studies until current low-level wind-measurement tests, using the unmodified aiming circle, are completed.

Wind computers were designed and fabricated to replace Nomogram ML-538( )/U. This nomogram consists of:

Nomogram A ML-538( )/U
Nomogram B ML-538( )/U
Wind Resolver ML-538( )/U
Strip, transparent, plastic with hairline, ML-538( )/U
Table for conversion of degrees to mils

The design of a circular slide rule, Modifications 17, 18, and 19, was undertaken in order to reduce the probability of making computational errors, to improve scale readability, to have all scales representing angular measurements plotted in mils, to reduce the physical size of the equipment, and to incorporate the complete calculation device into a single piece of equipment.

The completed computer consists of a base plate, two rotatable outer disks, and a hairline cursor. Most of the scales printed on the computer are influenced by wind-profile index (see reference 2). Two average profiles are used for this computer, thus enabling each side of the computer to represent one wind-profile condition. The sides of the computer are designated as "Side No. 1, Cloudy or Windy," and "Side No. 2, Nighttime and Light Winds." The wind-profile index used on Side No. 1 is 0.2, and the wind-profile index used on Side No. 2 is 0.4. Each side has eight scales.

The base plate is a plastic disk with two scales printed on each of its sides. These scales are the following:

A_2 Scale (Fig. 13). This scale uses azimuth-angle data obtained after tracking a balloon to the end of a given flight time. It is plotted differently on each side of the base plate. The range of the scale plot is from 150 mils to 1600 mils. Angles less than 150 mils, caused by a balloon flying closer to the baseline than this angle, would introduce a large error in the rocket-wind calculation. The color of the scale is white.

W Scale (Fig. 15). This scale yields the weighted-rocket wind speed when the data from a balloon run have been properly combined on the computer with a launcher setting and flight time. The scales are plotted differently on each side of the base plate. The plot on Side No. 1 ranges from 5 miles per hour to 50 miles per hour. Side No. 2 is graduated with wind-speed values from 1 mile per hour to 10 miles per hour. The color of the scale is white.

The outer disks have six scales printed on them. They are individually described as follows:

Mils Scale (Fig. 11). In tracking the balloon, observers will usually read angles that are greater than 1600 mils. The computer is graduated to only 1600 mils of arc, and all angular data which are greater than 1600 mils must be converted to a value less than 1600 mils before a calculation can be made. The purpose of the mils scale is to make the necessary conversion. It is divided into 80 parts, and each division represents 20 mils. Every fifth division is numbered with four numbers in a column. These numbers represent hundreds of mils. Conversion of an angle greater than 1600 mils to one less than 1600 mils is made by locating the number to be converted in the second, third, or fourth rows of numbers and by reading the number which appears in the first row. The color of the scale is white, and it is printed the same on both of the outer disks.

QE Scale (Fig. 12). This scale is marked with the quadrant elevation angles at which the rocket launcher may be set. The layout of this scale depends on rocket characteristics and, therefore, it is plotted for use with a specified free-rocket-and-launcher combination. The factor F (see reference 2) of the rocket-wind equation must be known in order to plot the

scale. This factor varies with the quadrant elevation of the launcher and depends on the wind-influence function of a rocket, on the length of the baseline between tracking instruments, and on the wind-profile index. The range of the scale is from 200 mils to 900 mils. It is printed differently on each of the outer disks. Its background color is red.

Time Scale (Fig. 12). This scale is used to obtain the balloon-flight time, which depends on the quadrant elevation (QE) at which a rocket is to be launched. The time scale is plotted in reference to the QE scale. The functional relationship between QE and optimum flight time depends on the characteristics of a specific type of rocket and its launcher. The color of the scale is green and it is plotted differently on each of the outer disks.

A_2 - A_1 Scale (Fig. 13). This scale represents the difference between the two azimuth angles obtained after tracking a balloon to the end of a given flight time. The difference measurement enters the rocket-wind-speed calculation influenced by the wind-profile index. Therefore the scale is plotted differently on each of the outer disks. The printed graduations range from 50 to 1000 mils on Side 1 and from 25 to 1400 mils on Side 2. The scale background is yellow.

E_1 Scale (Fig. 14). This scale uses elevation-angle data obtained by the Station 1 aiming circle at the end of the tracking period. It is used in conjunction with the A_2 scale and the A_2 - A_1 scale in calculating rocket wind. Its plot differs on each of the outer disks. The graduations range in value from 10 mils to 1500 mils on Side No. 1 and from 20 mils to 1350 mils on Side No. 2.

R Scale (Fig. 15). This is the outermost scale of the calculator. It is used to resolve the wind-speed value obtained on the W scale into cross-wind speed and range-wind speed. This calculation is done by using the wind-speed value and a wind-direction figure obtained from the balloon flight and orientation procedures that result in a direction referred to the intended line of flight of the rocket. This scale is plotted on both of the outer disks in the same way. The background color of the scale is gray, and the range of the plot is from 103 mils to 1600 mils.

Each outer disk also has a legend area printed in its central area (Fig. 10). This area contains computer nomenclature, the computer side numbers, the name of the rocket with which the computer is to be used, eight steps to be used as a wind-speed calculation guide, seven steps to be used as a wind-component calculation guide, and a table to determine from which direction this range wind and cross wind are blowing.

The cursor is made of transparent plastic and marked with a hairline (Fig. 9). The hairline extends from the inner scale to the outer scale of the computer, and it has symbols and words printed on it which indicate the function of each scale.

This computer design can be adopted for use in getting the weighted rocket wind for any free rocket and launcher system whose characteristics are known. These characteristics affect only the plotting of the QE and time scales. The Computers, CP-553(XE-1)/UM and CP-554(XE-1)/UM, which are included in the wind-measuring set, were designed for use with the Honest John

M-31 rocket on the M-289 launcher and with the Littlejohn rocket on its standard launcher.

The stop watch (Modification 20, Fig. 7) can be started, stopped, and then restarted by depressing the crown. By depressing an additional pin that is on top of the case, the timing hand will return to zero.

A worksheet (Modification 2b, Fig. 23) has been designed for use in conjunction with the computer. It is used to record date, time, observers, quadrant elevation, and balloon-flight time. It also provides space to calculate and record the angle of orientation between the baseline and the intended line of fire of the rocket, to record balloon-tracking data, and to record the wind-speed value obtained from the computer. There is also space for recording the data that are necessary to calculate the wind direction in relation to the line of fire. Detailed instructions are given in reference 4.

Evaluation of System Accuracy

The most practical data on system accuracy can best be obtained from actual rocket firings in which the Wind-Measuring Set AN/TMQ-13 can be used in a field situation in conjunction with the Honest John and Littlejohn rockets. This type of data is not yet available; therefore, a brief review of the theoretical sources of error inherent in the AN/TMQ-3 is given. USASRDL Technical Report 2019 (reference 2) gives a detailed description of these errors.

Theoretical Accuracy

1. Observational Error. This is a broad term which includes many sources of error. It is variable, and its magnitude is dependent on wind speed, wind direction with respect to baseline orientation, quadrant elevation angle to be used, the prediction of wind-profile index, the observers, etc. Specific examples of observational error are given in the following tables:

Table 1

Wind Speed - 50 MPH

QE (mils)	Wind-Speed Error (mph)
900	1.5
620	1.2
400	1.0
200	0.6

Table 2

QE - 900 mils

Wind Speed (mph)	Error (mph)
50	1.5
40	1.0
30	0.6
20	0.2
10	0.1

The wind-profile index was taken as 0.2 in both tables, and the azimuth angle of the balloon from the baseline is taken as from 70 to 90 degrees. Table 1 applies with a constant wind speed of 50 mph, and Table 2 applies with a QE of 900 mils.

The observational error in a specific wind-speed measurement will increase as the azimuth angle of the balloon from the baseline decreases.

Therefore, a balloon flight along the direction of the baseline will have maximum error. In operation, a flight that travels 10 degrees or less from the baseline direction is rejected and the baseline reoriented.

2. Error Caused by Inaccuracy in Baseline Measurement. An error in wind speed is caused by laying out the baseline inaccurately. This wind error is directly proportional to the error in baseline measurement. On cleared level ground it is about ±1%, which results in an error of 0.5 mph in a 50-mph wind.

3. Timing Error. The stop watch used to time the balloon flight period is very accurate. However, the operator must release the balloon and start the timer simultaneously, and every operator would theoretically apply a slightly different error in trying to accomplish synchronized release action. A trained operator can accomplish this simultaneous balloon release and time-start action so that there is an error of not more than 0.1 second.

The observers who track a balloon flight are given a signal to indicate the end of the flight period. Trained observers end their tracking in synchronization with the end of time signal to within about 0.3 second.

The total timing error reflected in a maximum wind-speed error is ±0.4%.

4. Error Caused by Inaccurate Prediction of Wind-Profile Index. The profile index depends on a number of meteorological parameters. At present a sufficient quantity of data does not exist by which to assess the wind-speed error that may be caused by an erroneous prediction of this index. Error in wind speed is assumed to be minimized by allowing the balloon to rise to an optimum height for specific rocket firings.

5. Error Due to Wind Variance with Time and Distance. Some work has been done in this area. The vector standard deviation of wind speed given in reference 2 needs more data at a variety of wind speeds to test its validity.

6. Computational Error. The master plates from which the wind computers are printed are accurately laid out and any error due to the mechanical construction of computers is negligible. Trained operators should not make computational errors in excess of .25 percent. This magnitude of error will result in a ±1 mph error in wind.

7. Other Error Sources. Additional system errors could be contributed by the following:

Orientation of the aiming circles.

Inaccuracy of the aiming circles.

Erroneous reading of the aiming-circle scales.

Erroneous reporting of the readings.

Inability to lock-in on the balloon at the end of flight time.

Incorrect estimation of angles values when the setting is between division marks.

Variation in the rate of rise of the balloon.

Vertical air current.

CONCLUSIONS

1. The wind-measuring set described in this report has many intrinsic sources of error, and at the present time definite values for some of them are indeterminate. Therefore, it is impossible to make an over-all accuracy statement for the system.

2. Difficulties experienced with the first model were caused by improper construction and by a poor selection of components rather than by the theoretical concepts of the basic wind-measuring set. Redesign and the use of improved components appear to have made this wind-measuring set quite satisfactory for tactical applications.

RECOMMENDATIONS

1. Wind-Measuring Set AN/TMQ-13 should be field-tested in conjunction with rocket firings. Existing low-level wind-measuring equipment should be used simultaneously so as to compare accuracies and to determine what improvement this system offers over the standard equipment now in use.

2. The wind-measuring set should be tested in conjunction with the USASRDL wind range so that a wind-speed-measuring-accuracy comparison may be made with other systems that have been and will be tested on the range.

3. The components of this set should be tested under tactical conditions to determine if any defects exist.

4. A semiautomatic timer of simplified design should be considered as well as the stop watch submitted with this set. This type of timer would be manually started on its timing cycle; then it would automatically time a preset interval, transmit a signal over the telephone system, and shut itself off.

5. A special stop watch with a reversed scale ranging from 100 to 0 seconds should be considered if the semiautomatic feature of recommendation 4, above, is not desired.

ACKNOWLEDGMENTS

The authors appreciate all the assistance given them throughout the development of this equipment. Acknowledgment is made of the efforts of Mr. J. Kurman on several phases of the engineering and testing and of the work of Messrs F. Fine and C. Dresser, who operated the equipment during testing.

REFERENCES

1. Letter, SIG-5B-1 (Low-Level Wind), from OCSigO to CO, USASRDL, Fort Monmouth, N. J., subject: "Report of Evaluation of Double-Theodolite System for Measuring Low-Level Wind," dated 29 May 59.

2. Barichivich, A. C.; Weisner, A. E.; Arnold, A.; Conover, W. C.; and Sartor, E. E., "Double Theodolite Wind-Measuring Set for Rockets," USASRDL Technical Report 2019, Mar 59.

3. Sartor, E. E., "Evaluation of Aiming Circle Equipment M2 for Tracking Pilot Balloons," USASRDL Test Report 1482, Jun 60.

4. "Service Test Instruction Manual for Wind-Measuring Set AN/TMQ-13, Operating and Organizational Maintenance Instructions, Revised," USASRDL publication.

APPENDIX

HEADQUARTERS
U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY

27 June 1960

SIGFM/EL-SMS
3D36-03-001-02

MEMORANDUM FOR: Chief, Meteorological Systems Branch

S U B J E C T : Comparison of Portable Helium Cylinders and Hydrogen Generator ML-303/TM for Inflation of Pilot Balloons

1. Purpose:

The purpose of this memorandum is to compare the use of small portable helium cylinders versus Hydrogen Generator ML-303/TM for the inflation of pilot balloons.

2. Background:

A double-theodolite system for measuring low-level wind was evaluated by the U. S. Army Artillery Board at Fort Bliss, Texas, and by White Sands Missile Range, New Mexico, in conjunction with tests that were conducted by the U. S. Army Signal Research and Development Laboratory. As a result of this evaluation, it was requested through OCSigO that a study be prepared to compare the logistic factors involved in the use of hydrogen generators versus helium cylinders to support Honest John and Littlejohn units under tactical conditions.

3. Discussion:

a. A series of test inflations was made at USASRDL, Evans Area, Belmar, New Jersey, using Hydrogen Generator ML-303/TM with Calcium Hydride Charge ML-304 A/TM. It was found that one 30-gram pilot balloon could be inflated to the required 20-gram nozzle lift approximately five minutes after the shelter and hydrogen-generator equipment were ready. It was possible to inflate two 30-gram balloons with the one ML-304 A/TM charge provided only half the holes in the can were punched out. When all the holes were punched, the rate of generation was very rapid, and too much gas was lost during the balloon weigh-off-and-charge procedure. When using a Weather Bureau night light (activated weight, 20 grams), only one 30-gram balloon could be inflated per Calcium Hydride Charge ML-304 A/TM.

b. As an alternate, a system using helium was designed that consisted of small, lightweight cylinders (5 1/4 inches by 17 3/4 inches, including value) containing approximately ten cubic feet of helium, a portable a-c operated air compressor, and tubing to be used for transferring the helium from the cylinder to the balloon. One cylinder, when filled to capacity, can inflate six to eight 30-gram balloons without load. When the cylinder is empty, it can be refilled easily in rear areas by following the procedure outlined in the operator's instruction manual.

c. Some of the advantages of the helium bottle over the Hydrogen Generator ML-303/TM are as follows:

(1) No explosion or fire hazard exists with helium.

(2) The item requires less space than hydrogen-generating equipment under tactical conditions. No accessory equipment, such as water container, grounding cables, etc., is required; nor is a source of water needed.

(3) Before a baseline can be laid down, a balloon has to be released to determine wind direction. The generation of hydrogen at this point would cause an additional time loss of ten minutes. The helium cylinder, however, is immediately available for inflation.

(4) The helium cylinder can inflate six to eight pilot balloons with the required lift, so if a balloon breaks or another balloon-release is required, the gas is instantly at hand. A new generation might be required with Hydrogen Generator ML-303/TM, causing further delay.

(5) The balloon can be weighed off more easily when using the helium cylinder, since the only action involved is closing a valve. Furthermore, no gas is wasted. The hydrogen generator cannot be shut off and continues to generate gas until all the calcium hydride charge is expended.

(6) Since the generation of hydrogen requires water, the use of Generator ML-303/TM in the Arctic or in other very cold locations would be extremely difficult.

(7) Troops would require more instruction time in the use of the hydrogen generator than in the use of the helium bottle.

(8) The initial cost of the helium bottle system (exclusive of the air compressor) and the hydrogen-generator system is about the same ($35 to $40). The cost of the helium, however, is considerably less than that of hydrogen produced from calcium hydride. One Calcium Hydride Charge ML-304 A/TM yielding six cubic feet of hydrogen costs $1.42, whereas a tank of helium containing 200 cubic feet of the gas costs $4.28. Thus, calculating that one would be able to inflate a minimum of 100 pilot balloons (without load) with one tank of helium (since there is very little loss of gas using the recommended system), the same number of balloons would require a minimum of 50 ML-304 A/TM charges (a cost of $4.28 compared to $71.00, exclusive of transportation costs).

d. Some disadvantages of the helium bottle system are as follows:

(1) An air compressor to accompany each system costs approximately $650. However, this would soon be compensated for by the much cheaper cost of the helium.

(2) The part of the helium bottle system used in tactical situations weighs approximately 11 pounds, as does Hydrogen Generator ML-303/TM. However, the weight of calcium hydride charges required for inflation of

100 pilot balloons with a nozzle lift of 20 grams is only 37 percent that of the weight of a 200-cubic-foot tank of helium.

(3) It is necessary to ship the large helium tanks in two directions since they must be returned for refilling. The calcium hydride charges are expendable and consequently shipment is in one direction only.

4. Conclusion:

Since the small helium cylinder system offers great operational advantage over Hydrogen Generator ML-303/TM, it is recommended that it be used to support Honest John and Littlejohn units under tactical conditions. A complete system is being submitted together with Hydrogen Generator ML-303/TM for service-test evaluation with Wind-Measuring Set AN/TMQ-13 by USCONARC. It is believed that this application is sufficiently important to warrant the use of helium, which is a strategic material.

/s/ Ruth Welt
RUTH WELT
Engineering Technician
Aero Instrumentation

Reviewed by:

/s/ K. C. Steelman
K. C. STEELMAN
Chief, Aerological Instrumentation Section

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The general development of Wind-Measuring Set AN/TMQ-13(XE-2) is discussed, and a detailed review is made of the design-modifications that have been incorporated in the service-test model. A brief summary is made of the theory of design and of the system errors.

1. Development
2. Design Modifications
3. Theory of Design
4. System Errors

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